Second Generation Wallops Fine Sun Sensor

Wallops Flight Facility
Goddard Space Flight Center
National Aeronautics and Space Administration

Features

- Panel mountable – only required internal bus space is for harnessing
- Onboard processor – places no additional burden on flight computer
- High accuracy – estimated 3-σ uncertainty around 10 arcminutes
- Low power – estimated peak power consumption less than 50 mW
- Configurable – housings and filters can be adjusted to meet mission needs

Sensor Theory

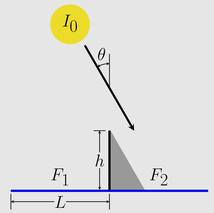
A cruciform shade casts differing proportions of shadow on individual diode quadrants, giving a unique set of measured fluxes from each quadrant at a given orientation:

$$\mathrm{F_1} = \mathrm{I_0 cos\theta L}$$
$$\mathrm{F_2} = \mathrm{I_0 cos\theta (L - htan\theta)}$$

Using a ratio of the difference between fluxes over the total flux sum gives a relationship that is independent of intensity, $\mathrm{I_0}$:

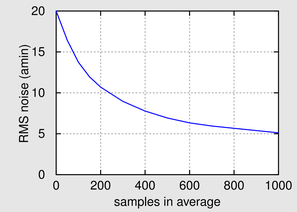
$$\frac{\mathrm{F_1 - F_2}}{\mathrm{F_1 + F_2}} = \frac{\mathrm{htan\theta}}{\mathrm{2L - htan\theta}}$$

This relationship can be solved for θ. However, to account for real world variations and to allow for both axes to be used simultaneously, the relationship between θ and the flux ratio is calibrated and table lookups are used on the sensor.



Performance Improvements

Digital Filtering

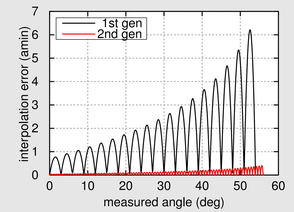


No digital filtering was used on the first generation sensor, but the primary source of measurement uncertainty is random noise. The improvements in processing speed and sampling frequency will allow for the addition of digital filtering. A moving average filter can smooth out the random noise at the cost of measurement lag. A configurable filter will allow missions to strike the appropriate balance between accuracy and response time.

16 Bit ADC

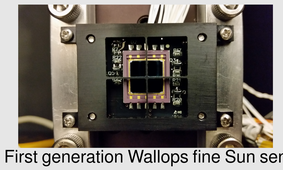
The bit resolution of the first generation sensor with the 12-bit ADC is approximately 3 arcminutes. With the improvements in the second generation design, the expected bit resolution will drop to around 0.15 arcminuntes.

Resolution of Table Lookup



The lookup table accuracy on the first generation sensor is limited primarily to processor memory. The increase in memory with the new processor will allow for larger tables to be used. Interpolation errors are predicted to improve from 5 arcminutes to around 0.3 with the new processor.

First Generation Sensor

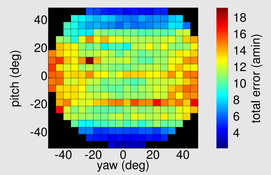


First generation Wallops fine Sun sensor.

Specifications

Mass:	15 g
Dimensions:	54.5×32.3×6.4 mm
Power:	0.25-0.4 W
Accuracy:	30 amin (3-σ)
FOV:	>100°

- PIC18 processor
- Photoconductive circuit with reverse bias
- 12-bit ADC
- 10×10 mm quad photodiode
- 3 mm cruciform shade
- ~2° resolution in lookup table



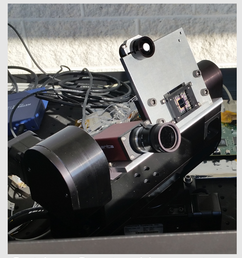
Typical error field for first generation sensor.

Interface

• Power:	±3 VDC
• Communication:	RS-232, RS-422, SPI, I²C, configurable for other protocols, configurable for full handshaking
• Data:	Sun unit vector, temperature, raw diode counts, field of view flags

Outdoor Calibration

- Arcsecond accuracy reference Sun sensor
  - Precision aligned to WFSS mounting plate using theodolite
- Reference pyranometer to reject readings through cloud cover
- Two-axis gimbal platform
- Baffle surrounds tracking system to reduce reflected light from surroundings



Outdoor Sun tracking system.

Advantages

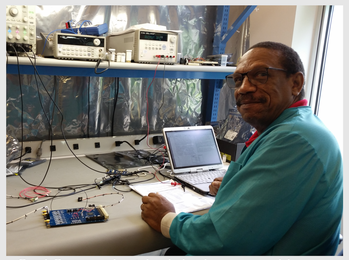
- Natural sunlight
- Precision alignment to light source
- Mobile – can be used anywhere

Disadvantages

- Difficult to control environment
- Reference Sun sensor has limited FOV
- Weather dependent

Changes from First Generation Design

- Photoconductive circuit replaced by photovoltaic circuit with transimpedance amplifier
  - Inherent circuit noise greatly reduced
- PIC18 processor replaced by SAM4L
  - Increased SRAM from 1.5 kb to 32 kb
  - Increased flash memory from 32 kb to 256 kb
  - Floating point processor
  - 32-bit words (faster processing)
  - Can support lookup table resolutions under 0.7°
- Added 16-bit ADC for diode measurements
- Increased sample rate to allow for digital filtering
- Decreased detector to 5×5 mm size
  - Power draw proportional to solar flux – reduced detector amplifier power by 75%
  - Cruciform shade height can be reduced by half for the same field of view, making the sensor thinner overall
- Added detector power switching capability



Carl Snow, electrical designer, working on development board.

Solar Simulator Calibration



First generation sensor during solar simulator calibration.

- Class ABA solar simulator
  - Calibration centered on region in beam where class A uniformity is found
- Two-axis gimbal platform with encoder position feedback
  - Orientation knowledge to 0.79 arcseconds
- Enclosure to prevent stray light

Advantages

- Consistent, controlled environment
- Not weather dependent
- Simple gimbal orientation

Disadvantages

- Artificial light source
- No alignment reference to light source

Future Work

- Perform environmental qualification
  - Thermal vacuum
  - Vibration
- Evaluate need for radiation hardening
- Housing design improvements
  - Make various shade heights to customize accuracy and field of view to mission requirements
  - Add neutral density filter to reduce UV aging and detector power



Tom Gadson, electrical technician.

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